The formation and evolution of galaxies III: Cluster galaxies

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Scientific category: DISTANT GALAXIES
Instruments: OPT/CAM, NIR/CAM, NIR/SPEC
Days of observation: 21

Abstract

Rich clusters of galaxies are interesting as the most massive gravitationally bound objects in the Universe. Although containing only about 1 % of all galaxies, they provide an environment for the formation and evolution of galaxies that is unique, and in many regards, the population of galaxies seen today in rich clusters differs from that found in the field. We therefore propose to complement the DRM programs that are targeted at field galaxies with similar observations of 20 rich clusters (or their progenitors) at $1 < z < 5$.

Observing Summary:

Target	RA	Dec	m_{AB}	Configuration/mode	Days
IMAGINGX7	TBD	TBD	33 at I	OPT/CAM R3	3
IMAGINGX20	TBD	TBD	32.5 at L	NIR/CAM R3	7
DIAGNOSTICX7	TBD	TBD	27 at L	NIR/SPEC R1000	7
KINEMATICX20	TBD	TBD	27 at L	NIR/SPEC R5000	7
KINEMATICX7	TBD	TBD	22 at N	NIR/SPEC R5000	7
				Grand total days	31

NOTE: This grand total (31) does not equal the number (21) given on page 1

Scientific Objectives

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Understanding the formation and evolution of galaxies at high redshifts is a central topic of the Origins program and a major theme of the NGST DRM. Previous DRM proposals are aimed at carrying out deep imaging and spectroscopic surveys that are designed to yield a definitive understanding of the field galaxy population in the $1 < z < 5$ redshift range and proto-galactic units at even higher redshifts (in principle to $z \sim 20 - 40$). Field galaxies are selected randomly without regard to their cluster environments and are thus "typical" galaxies and the high redshift galaxies studied in these programs will evolve into galaxies similar to the Milky Way and other galaxies seen around us.

However, about 1% of galaxies at the present epoch are found in rich clusters of galaxies. Rich clusters are of intrinsic interest in that they represent the most massive gravitationally bound structures in the Universe, with masses of order $10^{15} M_{solar}$. The number density of such structures in the Universe is thus a sensitive measure of the amplitude and gravitational growth of the density spectrum on large scales.

Rich clusters of galaxies represent a unique environment for galaxies in many ways: (a) the average number density of galaxies is much higher than in the field; (b) there is a hot high pressure intergalactic medium; (c) in many cases there is evidence for the deposition of large amounts of baryonic material out of the hot intergalactic medium in the form of "cooling flows"; (d) the interactions between galaxies are at much higher velocities in clusters. Finally, even before the cluster forms, the collapsing density fluctuation has an average density much higher than surrounding regions, mimicing the dynamical environment of a super-critical Universe with $\Omega > 1$.

There are many indications that the formation/evolution of galaxies in these unusual environments has indeed proceeded differently from more typical "field" galaxies but it is not clear whether these primarily reflect differences in the initial formation of the galaxies (in regions of slightly higher average density) or in the subsequent evolution in a different environment. Examples of these pronounced differences include (a) the mix of different morphological types is different in rich clusters than in the field, with a much higher fraction of early type galaxies that do not show evidence for ongoing star-formation; (b) the elliptical galaxies at $0 < z < 1$ display a tight colour magnitude relation, suggesting an early and homogeneous formation of their constituent stellar populations; (c) clusters also display a large population of dwarf elliptical galaxies not present in the field, and (d) the central cD galaxies (the most massive and luminous galaxies in the Universe) display a number of unique properties.

Because it is gravitationally bound to the cluster, the intergalactic medium is also more easily studied in rich clusters of galaxies than in the field. A major unanswered question concerns the origin of the metals in the intergalactic medium (with a metallicity of approximately 1/3 solar, the intergalactic medium contains more metals than the galaxies in the cluster).

Understanding the evolution of galaxies in clusters thus represents an important aspect of the general problem, and the proposed program is directed at addressing the following questions by contrasting the appearance and detailed properties of galaxies in young clusters at the highest possible redshifts with those in the field. Key questions are as follows:

- Why did star formation stop at an early epoch in the giant ellipticals?
- What is the origin of the heavy elements seen in the intergalactic medium?
- What is the origin of the dwarf elliptical population?
- When did the cores of the great clusters form?

Our proposed strategy is to observe galaxies in rich clusters of galaxies at high redshifts ($z > 2$) in the same way as field galaxies will be observed with imaging and spectroscopic observations so as to allow comparisons to be made in the detailed properties of the galaxies. While the "field" surveys of random parts of the sky will sample galaxies in groups such as the Local Group, they will not cover sufficient volume to yield large numbers of rich clusters and such environments must be studied with pointed observations at previously identified clusters.

Almost no clusters are presently known at $z > 1$ (the number density of such clusters would set strong constraints on cosmogonic models) but several indications suggest that the ellipticals in the cores of such clusters formed at higher redshifts and therefore that these proto-cluster cores should be detectable at $z > 2$. Several search strategies show promise for finding such cluster cores in the future including the detections of clusters through the Sunyaev-Zeldovich effect (the S-Z signal is independent of distance) producing secondary anisotropies on the CMB. The next generation of X-ray satellites will likely also find clusters at high redhsifts, while deep wide-field imaging surveys on ground-based telescopes should also yield samples of clusters at $z >> 1$.

We propose to observe a future sample of such clusters at the highest possible redshifts with observations that are as similar as possible to those of the field surveys. In fact, the nature of the clusters and the prior knowledge of their redshifts should lead to an increased efficiency of the observations. For instance, fewer filters need be used (probably three instead of eight) and the multiplexing gain of the slit masks should be increased. If possible, seven such clusters will be studied as follows:

(a) Imaging: In three filters placed at rest wavelengths of approximately 2000 Å, 4000 Åand 8000 Åto the depth of wide field imaging survey (total exposure time 1.3 days).

(b) Diagnostic spectroscopy One mask at R=1000 to observe of order 100 cluster galaxies in the rest-frame $3500Å < \lambda < 7000Å$ region, to a depth comparable to the field survey (exposure time 1 day).

(c) Kinematic spectroscopy One mask at R=10000 to observe of order 100 cluster galaxies in Hα, to a depth comparable to the field survey (exposure time 1 day).

NGST Uniqueness/Relationship to Other Facilities

Please see associated imaging and spectroscopic survey DRM proposals.

Observing Strategy

Explained in detail in context of science above.

Special Requirements

Minimum Spatial Resolution:	0.1 mas at 2 μm
Minimum Spectral Resolution:	10000 at 1-5 μm
Minimum FOV:	2? arcmin^2 at 1-5 μm
RMS offset accuracy:	15 mas
RMS repointing accuracy:	15 mas

Precursor/Supporting Observations

The target clusters must be found! CMB anisotropy measurements should yield S-Z candidates, and deep imaginging from the ground should also work. X-rays also a possiblility.